

Review on Structural Analysis of Bevel Gear

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ABSTRACT

Transmission systems are used in various mechanical systems to transmit power from source to gears, chains. The bevel gear is one of the crucial components of power transmission system which required appropriate designing and optimal strength. The current work studies the various researches conducted in optimizing design and material of bevel gear using numerical and experimental techniques. The study also includes manufacturing process involved, contact stresses and application of FEA software in analysis of structural behaviour of bevel gears.

KEYWORDS: Bevel Gear, Structural analysis, Design optimization

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1. INTRODUCTION

In industries, many types of transmission systems are used to transmit mechanical power from source to destination such as belt drives, wire ropes, chains and gears etc. Among all the transmission systems, gear drives are widely used because of its high efficiency. Since it is a positive drive, gears are used in the range from smaller toys to larger ships. As the necessity increases, different gear materials, gear profiles are to be used to fulfil the needs. Power transmission takes place due to meshing action between two mating gears. Gear tooth failure occurs at mating point and root fillet as a result of repeated cyclic load. Excessive contact stress at contact point causes surface failure and bending stress developed at root fillet causes tooth breakage. A bevel gear is a type of gear which uses to transmit the power from one shaft to another shaft which is perpendicular to each other. In bevel gear the teeth are straight of straight bevel gear, which have a common apex point. And in spiral bevel gear the teeth are spiral curve which also have a common apex point. There is gradual contact in the teeth of spiral gear in which when the tooth of two gear meet with each other there is a smooth and noise less operation is done. Spiral bevel gear have more load capacity as there is simultaneously contact in the teeth and their arc of contact is greater. Bevel gear can be arranged at different pitch angle such that when the pitch angle is less than 90° then external bevel gear, when the pitch angle equal to 90° then crown bevel gear, and when the pitch angle is greater than 90° then internal bevel gear. There are specific categories of bevel gear which are Miter gear, Crown gear, internal bevel gear, Skew bevel gear, Hypoid gear, Zerol gear, Face gear

2. LITERATURE REVIEW

Chen B. et al [1] in 2015 conducted study on spatial curve meshing and its application for logarithmic spiral bevel gear. They targeted their study for the curve theory of gear transmission meshing for high performance applications. They studied different gear geometries and space curve meshing kinematics for design of a gear. From the space curve detailed study, they discuss about the conjugate curve theorem and their meshing. They used logarithmic spiral bevel gear theory and conjugate curve information and developed a mathematical model for conical-helix bevel gears. They have used ANSYS to validate their results developed by their mathematical model for specific profiles. They concluded known curve normal vector must be determined before finding the conjugate of space curve. Normal vector helps in determining the pressure angle for the tooth surfaces drawn. Relative curve magnitude acts as constraints for drawing proper meshing of tooth surfaces with arbitrary cross-sections from conjugate curve and known curve details.

Fong Z-H and Lin C-H [2] in 2015 numerically studied the tooth contact analysis of a bevel gear set by using measured tooth geometry data. They developed a numerical tooth contact analysis (NCTA) for single flank simulation by data measured on gear meshing centre. The contact pattern and corresponding transmission error been calculated by the position vector from their developed NCTA. The residual error for the surface fitting is almost around 100µm but residual error calculated by them is around 0.2µm. The bevel gear tooth surface measured by them by B-spline method was more effective. They compared contact pattern theoretical

results with QT (Quatree) search algorithm and with TE (Transmission error) by LRA (Least rotation angle) and found good agreement.

Kawasaki K et al [3] in 2015 studied the method for manufacturing large-sized skew bevel gears using CNC machining center. They proposed a method for remanufacturing pinion member using CNC machining of skew-bevel gear of large size. They modelled the skew bevel gear tooth surfaces numerically and mathematically. CMM has been used by them to measure the real gear tooth surface. They compared the CMM measured results with the simulation results. They formulated a polynomial expression for the deviation between the real and simulation results. Transmission error and tooth contact pattern shows the deviation has been designed and analyzed. Swarf cutting CNC machine has been used to produce pinion member. They also compared the deviation results with the analytical results for the pinion member manufactured by CNC.

Lopatin B. A. et al [4] in 2015 studied the involute helical-bevel gearing. In this study they dictated about the aspects during helical-bevel gear design. They concluded that involute gears can be designed for any shaft-axes position, parallel, intersecting or skew. For small interaxial angles less than 20° and taper angles less than 15° helical bevel gear (HBG) are most efficient they depends on the displacement coefficient of its faces. They concluded that HBG main advantage is that they can be manufactured on the same unit that of spur gears with same precision.

Kawasaki K. and Shinma K. [5] in 2014 designed and manufactured a straight bevel gear for precision forging die by direct milling. They targeted their study towards the increasing the production rate and reducing the cost of gear production. A quasi-complementary crown gear has been introduced by them instead of a conventional crown gear for generating the gear tooth profile. 3D-CAD has been used to model the gear tooth profile. First, they calculated the coordinates of the straight bevel gear tooth surfaces then the CNC milling machine has been used to generate the straight bevel gear by precision die casting. From their results they found that precision die casting helps in improvement of cost reduction and in increment in production rate.

Xuemei C. et al [6] in 2008 studied the design of pinion machine tool-settings for spiral bevel gears by controlling contact path and transmission errors. For their study they give three control points on the tooth surface and their study was based on the contact condition on the tooth surface of these given points. These three control points have been chosen based on the parabolic function of transmission errors. Magnitude of transmission errors and contact path orientation has been designed. They have also designed the blank offset which gives no effect on the transmission errors. A spiral bevel gear has also been designed on the Phoenix grinding machine to represents the calculated values from results.

Seok-Chul Hwang et al [7], had done the work on contact stress analysis for a pair of mating gears during rotation. Contact stress analysis is carried out on spur and helical gears during rotation at different contact points. The variation of the contact stress is compared at the lowest point of single-tooth contact with AGMA equation.

JongBoon Ooi, et al [8] have done research on modal and stress analysis of gear box used in portal axle. Contact and

bending stress analysis is carried out on three different gear configurations with varying angular positions from 0 to 18 degrees. The bending stress at the gear root fillet and the contact stress on the gear surface of the input and output gears are documented with every 2 degree of angular incremental. Contact stress was calculated analytically by Hertz equation. It is based on the analysis of two cylinders under radial load with an assumption of radius of the cylinder is equal to radius of pitch circle. Both contact and bending stresses were simulated in ANSYS workbench software with different boundary conditions. Finally, all the theoretical stress results are validated with FEM result.

Newton K. Fukumasu, et al [9] have done research on stress analysis of helical gear to improve contact resistance. The research mainly focused on contact stress analysis of helical gear and its relation with gear material properties and residual stress. The proposed gear was subjected to carbo-nitriding surface treatment and categorized by X-ray diffraction, nano-intendation and Vickers micro-hardness. The properties are fetched in to FEM and assessment was carried out. Finally, the author concluded that, the increase in the residual stresses causes the reduction of all sort of stresses at the contact point. It leads to improvement on pitting resistance at the surface of the tooth.

Bharat Gupta, et al [10] describes the contact stress analysis of spur gear. The objective of this work is to calculate the contact stress by using Hertz theory and compare with FEM results. Spur gear was modeled through parametric modelling in Pro-E software. Hertz stress was calculated for various module values from 2mm to 9 mm. The modeled gear was imported to ANSYS workbench for stress analysis. Contact stress at mating point is simulated and the corresponding results are obtained for various module values. It is concluded that, Surface failure can be prevented by increasing material hardness. From the Fig.4 it is revealed that the contact stress decreases with increasing module value.

Ali Raad Hassan [11] did a research work on Contact stress analysis between two spur gear teeth at different contact positions, during pure rotation of mating gears. A setup was established to ensure the pair of mating gears. During rotation for each and every location of contact the setup gives graphical results. FEM models were made and stress analysis was carried out.

Sarfraz Ali N. Quadri, et al [12] analysed the contact stress of involute spur gear. A pair of spur gear in a lathe has taken for analysis under static loading condition. Contact stress was calculated theoretically and compared with FEM results. The mating gears are modelled with 2 mm module in Creo 2.0 and then analysed in Ansys 14.5. Pinion is applied with fixed support whereas gear is applied with frictionless support as a boundary condition.

N. D. Narayankar, K. S. Mangrulkar [13] have worked on Contact Stress and Bending Stress Analysis of Spur Gear by Analytical Method. Finally the author concluded that the surface failure starts with the development of pits at mating point of gears leads to rupture of tooth. A pair of spur gears with 20° full depth have taken for analysis. Material for Pinion and gear is assigned as steel. Hertz contact stress is 169.22 N/mm² and Lewis bending stress is 200 N/mm². The gear is designed to withstand 15.4 kN load.

Ratnadeepsinh M. Jadeja, et al [14] studied on Bending Stress Analysis of Bevel Gears. Aim of this work is the estimation of bending stress developed at the root of tooth during the application of torque on straight bevel gear, spiral bevel gear and zero bevel gear. Bending stress was calculated numerically for straight bevel gear, spiral bevel gear and zero bevel gear derived from Lewis bending equation. Gears are modeled in PTC Creo. ANSYS workbench 14.0 is used to analyse the bending stress by FEM. For mesh, tetrahedron element type has chosen with 1 mm size at all faces and 0.5 mm at critical areas. Fixed support is taken as a boundary condition to obtain maximum bending stress for straight bevel. The same procedure was applied to other two gear types and results are obtained. From the analysis it is concluded that, straight bevel gear has higher strength to resist stress and it can take more load.

Amlan Das [15] carried out Finite Element Stress Analysis of Spiral Bevel Gear. Scope of this paper is to improve the transmission performance of the spiral bevel gear. Bending and surface stress of the tooth is prime causes for failure. It is mandatory to minimize the failure with an optimized design. Analytical calculations was done with AGMA equation and analysed in ANSYS 14.5. From the results it noted that increasing face width results decreasing contact and bending stresses. Tooth height plays a major role and it should not be modified unnecessarily. Shorted height should be avoided. AGMA and FEM results are compared and reveals that the FEM stress value is higher than AGMA.

S.Sai Anusha, et al [16] presented in their paper that focus on Contact Stress Analysis of Helical Gear by Using AGMA and ANSYS. Contact stress analysis is carried out on helical gear for different pressure angles, face width and helix angle. Gears are modeled in Peo-E software and analysed in ANSYS. An analytical approach is done based on Hertz equation.

S. K. Sureshkumar, S. Navaneethan [17] made an attempt on contact stress analysis of helical gear pairs of different helix angle. In this study, helical gear pairs are assigned with three different materials such as Steel, Cast Iron and Aluminium. Stress analysis is carried out by varying the helix angle. CATIA V5 is used to model the gears with different helix angle. Analysis is carried out in ANSYS.

3. CONCLUSION

Various researches are conducted to analyze contact stresses, its effects on gear life and parameters effecting contact stress. The findings have shown that magnitude of load applied, gear geometry and material are major factors which determine the life of gear. The study also discusses about different inspection methods for early detection of gear failures and methods to improve quality and life.

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